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Natural Gas Cooling in DOD Facilities

by

Chang W. Sohn
William T. Brown
Richard E. Rundus
Timothy W. Pedersen
Thomas E. Durbin
Michael A. Caponegro
Daryl Matsui

SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness through Environmental Research

Natural gas-powered cooling systems have been introduced in the market during the last decade as an alternative to electrically driven air-conditioning systems. To accelerate the introduction of natural gas cooling technologies to DOD facilities, funding was provided for Fiscal Years 1993-95 to procure gas cooling systems for DOD installations. This study reviewed the status of the natural gas cooling demonstration programs for DOD facilities to document the progress of the Congressional natural gas cooling projects in various stages of execution.

Natural gas cooling systems are currently in operation at 11 DOD installations, under construction at 23 installations, and in design at 8 installations. Preliminary reports from the DOD users in the field show that natural gas cooling systems have a strong potential for use in DOD facilities, even though a number of installations have reported problems in the early stages of system operation. Development of standard design guides and commissioning procedures will help DOD engineers eliminate such problems.

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Chang W. Sohn, William T. Brown, Richard E. Rundus, Timothy W. Pedersen, Thomas E. Durbin, Michael A. Caponegro, and Daryl Matsui

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Foreword

This study was conducted for Strategic Environmental Research and Development Program (SERDP) under Project 643, Work Unit UL-XP6, "Natural Gas-Based Air-Conditioning Demonstration." The technical monitor was Michael Hathaway, SERDP.

The work was performed by the Utilities Division (UL-U) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. Chang W. Sohn. Daryl Matsui is associated with the Naval Facilities Engineering Service Center (NFESC), Port Hueneme, CA. Chang W. Sohn is Acting Chief, CECER-UL-U; Martin J. Savoie is Acting Operations Chief, CECER-UL; and Gary W. Schanche is the associated Technical Director, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources.

COL James A. Walter is Commander and Dr. Michael J. O'Connor is Director of USACERL.

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Background

In response to the depletion of the ozone layer and its link to chlorofluorocarbon (CFC) and related substances, the United States and 22 other countries signed the Montreal Protocol in 1987. The protocol was developed by the United Nations Environmental Program (UNEP), and established phaseout schedules for the production and consumption of ozone-depleting substances. Later, the phaseout schedule was accelerated, and, in addition to CFC refrigerants, hydrofluorocarbon (HCFC) refrigerants were also scheduled for phaseout (London Amendments 1990; Copenhagen Revisions 1993). In the United States, the Clean Air Act Amendments of 1990 were enacted in November 1990. Title VI, "Stratospheric Ozone Protection," of the Clean Air Act (CAA) addresses issues related to protection of stratospheric ozone. The phaseout schedule for Class I substances was contained in Section 604 of Title VI in the CAA. Two years later, on 11 February 1992, President Bush unilaterally accelerated the production phaseout of all ozone depleting substances (Class I substances) to the end of 1995. Production of CFC refrigerants in the United States ceased effective 1 January 1996.

This refrigerant phaseout inevitably affects the U.S. military, which has a large investment in cooling equipment, and maintains its own stockpiles of refrigerants. Fiscal year 1995 (FY95) data show the total cooling capacity of air-conditioning equipment in the Army is 820,457 tons of cooling (Department of the Army [DA] FY95). The majority of the air-conditioning equipment in the Army is electrically powered (Sohn 1992). The Directorate of Public Works Annual Summary of Operations (DA 1995) shows that the Army's electrical bill in FY95 was over $555M. Typically, more than a third of the total electrical utility cost is incurred by operation of air-conditioning and refrigeration equipment. According to a detailed end use study of electrical energy at Fort Hood, TX, cooling is responsible for 54 percent of the peak power demand; 33 percent of the total electricity consumed was for cooling applications (Akbari and

Konopacki 1995). The annual electrical utility cost for providing air-conditioning for the Army is therefore estimated at over $200M. By verifying the Army's data with that of the Air Force and Navy, the electrical utility cost for air-conditioning all Department of Defense (DOD) facilities can be estimated at $600M per year.

The U.S. Army facility air-conditioning and refrigeration inventory includes approximately 2.5 million lb of refrigerants (Sohn, Homan, and Sliwinski 1992). Of this, 1.39 million lb (55.4 percent) are CFC- and HCFC-based refrigerants. CFC refrigerants are being used in fairly specific types of equipment: large chillers (air-conditioning loads of over 100 tons) and refrigeration/cold storage equipment. The remainder of the equipment serves smaller air-conditioning loads and generally uses HCFC-22 as the refrigerant.

Natural gas-powered cooling systems have been introduced in the market during the last decade as an alternative to the electrically driven air-conditioning systems. According to a Renewables and Energy Efficiency Planning (REEP) study (Nemeth et al. 1995), the annual savings potential by natural gas cooling systems for DOD facilities is estimated to be $70M. To accelerate the introduction of natural gas cooling technologies to DOD facilities, Congress provided $25M for the period of FY93-95 to procure gas cooling systems for DOD installations. SERDP contributed toward implementing gas cooling technologies in DOD installations. A number of gas cooling systems were also installed with support from the Federal Energy Management Program (FEMP). A review of the status of the natural gas cooling demonstration programs for DOD facilities was needed to document the progress of the Congressional natural gas cooling projects in various stages of execution.

Objective

The purpose of this study is to review the status of the natural gas cooling demonstration program for the DOD facilities and to document the progress of the Congressional natural gas cooling projects in various stages of execution, i.e., systems in operation in the field, systems under construction, and systems under feasibility study. Feedback information from the field engineers will be used to improve future design, procurement, construction, commissioning, and operation of natural gas cooling systems.

Approach

The status of natural gas cooling technologies available on the market was briefly reviewed. The criteria for selecting demonstration sites were presented and the typical project cycle was discussed. A list of natural gas cooling systems in DOD facilities was developed and feedback was gathered from the field to provide a global view of the infusion of the technologies in the DOD.

Scope

This study provides a general review of the status of the natural gas cooling demonstration program for the DOD facilities. Detailed discussion of field performance of individual systems is beyond the scope of this project.

Mode of Technology Transfer

It is anticipated that the SERDP Project Office will use the data gathered in this study to document the FY93-95 Congressionally directed procurement of natural gas cooling systems for DOD installations. The information in this report may then be used for updating the market penetration of natural gas cooling technologies in the REEP program. It is recommended that the results of this investigation be used to update Corps of Engineers Guide Specification (CEGS) 15995, *Commissioning of HVAC Systems* (01/93), and CEGS 15650, *Central Refrigerated Air-Conditioning Systems* (07/92). The information contained here may also contribute the development of a fact sheet on natural gas cooling systems for field engineers at DOD installations.

2 Demonstration of Natural Gas Cooling Technologies

Types of Natural Gas Cooling Systems

A variety of natural gas cooling technologies are available on the market today. Three generic types of natural gas cooling technologies are: (1) absorption chillers, (2) gas engine-driven chillers, and (3) natural gas-fired, desiccant cooling systems. Each type has a number of subclassifications depending on its capacity and operation cycle. A description of equipment and associated technology is readily available through manufacturers' product brochures, standard textbooks, and technical reports (Pedersen et al. 1996). Tables 1 and 2 list typical equipment currently available on the market (Sohn 1996).

Selection Criteria for Demonstration Systems

Potential sites were screened for candidacy by considering their electric and natural gas rate structures, cooling and hot water load profiles, and site-specific operating conditions. This process reduced the list of possible sites to only a few candidates. USACERL visited each site to determine the appropriate gas cooling technology for funding and to gather site-specific information concerning the design and estimated installation costs of the proposed system.

The desiccant cooling systems offer dehumidification capability and space cooling. A significant benefit is the system's ability to reduce micro-organism growth, and damage to facilities from condensation and corrosion. The capability identifies high potential facilities such as hospitals, health care centers, supermarkets, restaurants, water and wastewater treatment plants, enclosed swimming pools, and most commercial and institutional facilities located in humid climates.

The application of desiccant-based systems will vary, from add-on systems intended to increase the capacity of existing conventional systems, to complete systems that include a distribution system. Their size may range from small commercial to large, complex, multi-zone HVAC systems. USACERL evaluated potential demonstration sites. At selected sites, USACERL worked with the installation, local Corps of Engineer District, and local utilities to provide turn-key design, installation, commissioning, and training support. These field demonstrations will provide a basis to develop desiccant technology applications guidance for the DOD.

Table 1. Engine driven vapor-compression systems.

Capacity (tons)	Compressor	(COPc)e*	$/ton	Condenser Cooling
2000-6000	Centrifugal			Water
250-1040	Screw	1.32		Water
250-1100	Screw	1.57-1.81	513-760	Water
50-4000	Screw	1.0-2.0		Water
110-700	Screw	0.85-1.3	500-722	Water
50-300	Recip.	1.38-1.52		Water
25	Recip.	1.0		Air
95-315	Recip.		635-1000	Water
50-300	Recip.	1.0-2.0		Water
60-75	Recip.	0.95-1.3	917-1000	Water
15-25	Recip.	0.80	1088-1462	Air
3-4	Recip.	0.90	2000-2333	Air

* The coefficient of performance for refrigeration based on shaft work to remove heat at a temperature Tc is (COPc)e = Qc/Win., where Qc is the heat removed and Win is the shaft work which can be supplied by an engine

Table 2. Single-effect and double-effect absorption systems.

Capacity (tons)	Heat Source	(COPc)s	$/ton	Condenser Cooling
Single-effect absorption systems				
108-680	Steam	0.7	236-601	Water
112-1660	Steam	0.68	272-795	Water
5-10	Steam	0.7	2326-4640	Water
120-1377	Steam	0.69	205-590	Water
3-5	D.F.	0.48-0.62		Air
Double-effect absorption systems				
135-1000	D.F.	0.97	415-933	Water
100-1700	Steam	1.2	365-1104	Water
20-1500	D.F.	0.95-1.0	500-1700	Water
100-1500	Steam	1.4	400-900	Water
100-1100	D.F.	1.0	604-1320	Water
385-1125	Steam	1.2	446-683	Water
30-100	D.F.	0.95-1.0	718-953	Water
200-1000	D.F.	0.92	516-671	Water
440-1500	Steam	1.16-1.19	416-493	Water

Applications of the two-wheel desiccant system may be limited by high capital costs associated with low production levels and customized construction. This will improve as the user base expands. The best applications will have the following characteristics:

- critical need for low relative humidity (<50 percent)
- moisture loads equal to or higher than sensible heat loads
- high electric-to-natural gas energy price ratio (3:1, based on $/MBtu)
- a need to run dry cooling coils.

Typical Demonstration Cycle

The demonstration cycle for a typical site consists of site selection based on the selection criteria discussed earlier, development of engineering design and system specifications, award of a construction contract, installation of the system, commissioning and acceptance of the system, and monitoring of the operational performance.

Equipment purchase documentation was developed for the sites deemed to be good candidates for gas cooling technology. This document included equipment purchase, installation, start-up, acceptance testing, and first year warranty and maintenance information. Equipment purchasing, installation, and acceptance testing were completed for approved sites. The standard developed documentation was used as the basis for a Invitation for Bid (IFB), which was advertised for each implementation site identified. Upon contract award, USACERL personnel were available to assist in the design review stage and will be available for inspection of installed systems. USACERL representatives were also available to supervise and evaluate the acceptance testing results for the installed system.

Monitoring equipment was specified for each facility with the intent to record data for a span of 1 to 2 years. Performance monitoring will be used to determine the applicability of the particular technologies to DOD facilities as a whole. Both the technical and economical performance of the demonstration systems will be critical information in infusing gas cooling technologies to DOD installations.

Summary of Current Demonstration Program

A survey of natural gas cooling systems in DOD facilities, as of November 1996, was conducted. Tables 3 to 6 give a global summary of DOD installations with natural gas cooling system demonstrations. The tables list 42 major DOD installations with various types of systems currently either in operation or under design and construction. Including the number of DOD installations under evaluation, more than 50 DOD installations are actively participating in the natural gas cooling demonstration program. Table 7 describes systems at each site in detail. Table 8 lists points of contact at a number of demonstration sites.

Table 3. Summary of current demonstration programs—Army.

Installation	Facility Type	Project Funding	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)	CFM per Unit (if Desic)	Total Tonnage (if Eng or Absorp)	Total CFM (if Desic)	In Operation	No of Units in Operation	Under Construction	No of Units Under Construction	In Plan/ Design	No of Units in Plan/Design	In Interest
Ft Riley, KS	Irwin Army Community Hospital	Congressional	Engine	Chiller	2	300		600		Yes	2	No	0	No	0	
Ft Dix, NJ	Air Warfare Mobility Center	Congressional	Absorption	Chiller	1	340		340		No	0	Yes	1	No	0	
Ft Eustis, VA	McDonald Hospital	Congressional	Engine	Chiller	1	350		350		No	0	Yes	1	No	0	
Ft Bliss, TX	New Dining Facility	Congressional	Engine	Chiller	1	50		50		No	0	Yes	1	No	0	
Ft Polk, LA	Bldg 1941 - Central Energy Plant	Congressional	Engine	Chiller	1	570		570		No	0	Yes	1	No	0	
Ft Hamilton, NY	Daycare Center	Congressional	Engine	Chiller	1	25		25		No	0	Yes	1	No	0	
	Barracks Building	Congressional	Engine	Chiller	1	125		125		No	0	Yes	1	No	0	
Ft Huachuca, AZ	Hospital Building 45001	Congressional	Absorption	Chiller	2	145		290		No	0	Yes	2	No	0	
Ft Jackson, SC	Central energy plant	Congressional	Engine	Chiller	2	700		1400		Yes	1	Yes	1	No	0	
Barnes Bldg, Boston, MA (Ft Dix project)	Downtown office building		Engine	Chiller	1	700		700		No	0	No	0	Yes	1	
Ft Sam Houston, TX	Single family detached residential bldg	FEMP	Engine	Heat pump	1	3		3		Yes	1	No	0	No	0	
Ft Campbell, KY	Building 3214 (3rd Battalion)	FEMP	Engine	Chiller	1	250		250		Yes	1	No	0	No	0	
	Building 6944	FEMP	Engine	Chiller	1	360		360		Yes	1	No	0	No	0	
	Building 6921A	FEMP	Engine	Chiller	1	570		570		Yes	1	No	0	No	0	
	Building 6711	FEMP	Engine	Chiller	1	360		360		No	0	Yes	1	No	0	
	Building 6726	FEMP	Engine	Chiller	1	360		360		No	0	Yes	1	No	0	
	Building 6732	FEMP	Engine	Chiller	1	300		300		No	0	Yes	1	No	0	
	Building 6910	FEMP	Engine	Chiller	1	320		320		No	0	Yes	1	No	0	
	Building 6929	FEMP	Engine	Chiller	1	320		320		No	0	Yes	1	No	0	
	Building 6936	FEMP	Engine	Chiller	1	160		160		No	0	Yes	1	No	0	
	Building 6938	FEMP	Engine	Chiller	1	320		320		No	0	Yes	1	No	0	

Table 3. Cont'd.

Installation	Facility Type	Project Funding	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)	CFM per Unit (if Desic)	Total Tonnage (if Eng or Absorp)	Total CFM (if Desic)	In Operation	No of Units in Operation	Under Construction	No of Units Under Construction	In Plan/ Design	No of Units in Plan/Design	In Interest
	Building 3213	FEMP	Engine	Chiller	1	140		140		No	0	Yes	1	No	0	
	Building 6718	FEMP	Engine	Chiller	1	140		140		No	0	Yes	1	No	0	
	Don F Pratt Memorial Museum	FEMP	Desiccant	Dehumid unit	1		4000		4000	No	0	No	0	Yes	1	
Aberdeen Proving Ground, MD	Burger King	FEAP	Desiccant	Dehumid unit	1		2000		2000	Yes	1	No	0	No	0	
Ft Myer, VA	Barracks/O-Club	Army R&D	Desiccant	Dehumid unit	1		5000		5000	No	0	Yes	1	No	0	
Ft Benning, GA	Martin Army Community Hospital (Operating unit)	FEMP	Desiccant	Dehumid unit	1		5000		5000	No	0	Yes	1	No	0	
Redstone Arsenal, AL	Rocket Propellant Testing Facility	FEMP	Desiccant	Dehumid unit	1		10000		10000	No	0	No	0	Yes	1	
White Sands Missile Range, NM	Data Reduction Facility, Bldg 1526															Yes
Radford AAP, VA																Yes
Ft Gordon, GA																Yes
Ft Gillem, GA	New Gymnasium, Bldg 700															Yes
Ft McPherson, GA	FORSCOM HQ															Yes
Ft Knox, KY																Yes
McAlester AAP, OK	Health Clinic/Safety Office															Yes
Scranton AAP, PA	Administration Building															Yes

Table 4. Summary of current demonstration programs–Air Force.

Installation	Facility Type	Project Funding	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)	CFM per Unit (if Desic)	Total Tonnage (if Eng or Absorp)	Total CFM (if Desic)	In Operation	No of Units in Operation	Under Construction	No of Units Under Construction	In Plan/ Design	No of Units in Plan/ Design	In Interest
Robins AFB, GA			Engine	Chiller	2	1310		2620		No	0	Yes	2	No	0	
Davis-Monthan AFB, AZ			Engine	Chiller	2	650		1300		No	0	Yes	2	No	0	
Utah ANG, UT			Engine	Chiller	2	55		110		No	0	Yes	2	No	0	
MacDill AFB, FL	6th Medical Group Hospital	FEMP	Desiccant	Dehumid unit	1		18000		18000	Yes	1	No	0	No	0	
Keesler AFB, MS	Bowling alley	FEMP	Desiccant	Dehumid unit	1		5000		5000	No	0	Yes	1	No	0	
Youngstown-Warren Air Reserve Station, OH	Airlift Wing Head-quarters		Engine	Chiller	1	140		140		No						Yes

Table 5. Summary of currrent demonstration programs–Navy.

Installation	Facility Type	Project Funding	Type of NG Cool-ing	NG Cool-ing Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)	CFM per Unit (if Desic)	Total Tonnage (if Eng or Absorp)	Total CFM (if Desic)	In Opera-tion	No of Units in Opera-tion	Under Construc tion	No of Units Under Construc tion	In Plan/ Design	No of Units in Plan/ Design	In Interest
Naval Air Station, Jacksonville, FL	Allegheny Circle Housing Area	Congressional	Engine	Heat pump	10	3		30		No	0	Yes	10	No	0	
	Building 919 - Data Processing															Yes
Naval Air Station Joint Reserve Base, Fort Worth, TX	Carswell Housing Area	Congressional	Engine	Heat pump	7	3		21		No	0	Yes	7	No	0	
National and Naval Hospital, Bethesda, MD	Hospital	Congressional	Absor ption	Chiller	1	1000		1000		Yes	1	No	0	No	0	
Naval Training Center, Great Lakes, IL	Building 237 - Medical and Dental Clinic	Congressional	Absor ption	Chiller	2	268		536		Yes	2	No	0	No	0	
	Building 1405 - Administrative Support Office	Congressional	Absor ption	Chiller	1	400		400		No	0	Yes	1	No	0	
Naval Air Station, Miramar, CA	Building 515 - Electronics/Hydraulics Maintenance Training	Congressional	Absor ption	Chiller	1	180		180		Yes	1	No	0	No	0	
Naval Air Station, Willow Grove, PA	Base Exchange (BX)	FEMP	Engine	Roofto p A/C unit	2	15		30		Yes	2	No	0	No	0	
	Multipurpose Library	FEMP	Engine	Split system A/C unit	1	15		15		Yes	1	No	0	No	0	
	Building 180 - Aircraft Intermediate Maintenance Department	Congressional	Absor ption	Chiller	1	80		80		No	0	Yes	1	No	0	
	Building 180 - Aircraft Intermediate Maintenance Department	FEMP	Desicc ant	Dehumi d unit	1		5000		5000	No	0	Yes	1	No	0	
Fleet Combat Training Center, Damneck, VA	Building 543 - Guided Missile School	Congressional	Absor ption	Chiller	1	210		210		No	0	Yes	1	No	0	

Installation	Facility Type	Project Funding	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (If Eng or Absorp)	CFM per Unit (If Desic)	Total Tonnage (If Eng or Absorp)	Total CFM (If Desic)	In Operation	No of Units In Operation	Under Construction	No of Units Under Construction	In Plan/ Design	No of Units in Plan/ Design	In Interest
Submarine Base New London, Groton, CT	Building 488 - Bachelor Enlisted Quarters	Congressional	Absorption	Chiller	1	175		175		No	0	Yes	1	No	0	
Naval Education and Training Center, Newport, RI	Building 95 - Officers Club	Congressional	Absorption	Chiller	1	130		130		No	0	Yes	1	No	0	
Naval Air Weapons Station, Point Mugu, CA	Building 50 - Laboratory	Congressional	Absorption	Chiller	1	100		100		No	0	Yes	1	No	0	
Navy Public Works Center, Naval Air Station, Pensacola, FL	Environmental Building	FEMP	Desiccant	Dehumid unit	1		1590		1590	Yes	1	No	0	No	0	
Naval Hospital, Camp Pendleton, CA	Naval Hospital	Congressional	Absorption	Chiller	1	800		800		No	0	No	0	Yes	1	
Naval Air Station, Atlanta, GA	Bldg 1 - Aircraft Intermediate Maintenance Dept	Congressional	Engine	Chiller	2	50		100		No	0	No	0	Yes	2	
	Bldg 2 - Training Facility	Congressional	Engine	Chiller	1	75		75		No	0	No	0	Yes	1	
	Bldg 5 - Hangar	Congressional	Engine	Chiller	1	30		30		No	0	No	0	Yes	1	
	Bldg 550 - Medical Clinic	Congressional	Engine	Chiller	1	80		80		No	0	No	0	Yes	1	
Naval Air Weapons Station, China Lake, CA	Building 5 - Michelson Laboratory	Congressional	Engine	Chiller	2	750		1500		No	0	No	0	Yes	2	
Fleet Industrial Supply Center, Norfolk, VA	Building W-143	Congressional	Engine	Chiller	1	250		250		No	0	No	0	Yes	1	
	Building W-133															Yes
Naval Construction Battalion Center, Port Hueneme, CA	PWC Building 850	Congressional	Engine	Heat pump	1	3		3		No	0	No	0	Yes	1	
Navy Air Depot, Jacksonville, FL	Building 101 - Tube and Hose Shop	FEMP	Desiccant	Dehumid unit	1		5000		5000	No	0	No	0	Yes	1	

Installation	Facility Type	Project Funding	Type of NG Cool-ing	NG Cool-ing Equip Type	Total No of Units	Tons per Unit (If Eng or Absorp)	CFM per Unit (If Desic)	Total Tonnage (If Eng or Absorp)	Total CFM (If Desic)	In Opera-tion	No of Units in Opera-tion	Under Construc tion	No of Units Under Construc tion	In Plan/ Design	No of Units in Plan/ Design	In Interest
	Aircraft Maintenance & Repair															Yes
Naval Air Station, Corpus Christi, TX	Building 8 - Admin, Repairs, Maint, Testing															Yes
Fleet Industrial Supply Center, San Diego, CA	Building 1 - Administrative															Yes
Fleet Combat Training Center, San Diego, CA	Building 24 - Training Facility															Yes
Naval Air Station, Whiting Field, Milton, FL	Building 2946 - Aircraft Simulator															Yes
Naval Air Oceana, VA	Building 419 - Enlisted Barracks															Yes

Table 6. Summary of current demonstration programs—Marine Corps.

Installation	Facility Type	Project Funding	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)	CFM per Unit (if Desic)	Total Tonnage (if Eng or Absorp)	Total CFM (if Desic)	In Operation	No of Units in Operation	Under Construction	No of Units Under Construction	In Plan/ Design	No of Units in Plan/ Design	In Interest
Marine Corps Air Station, Yuma, AZ	Building 663: 2 Barracks & Lounge	Congressional	Absorption	Chiller	1	300		300		Yes	1	No	0	No	0	
Marine Corps Air Ground Combat Center, 29 Palms, CA	Building 1748-1859: C&E School		Engine	Chiller	1	300		300		No	0	Yes	1	No	0	
	Building to be determined	Congressional	Engine	Chiller	1	100		100		No	0	No	0	Yes	1	
Marine Corps Logistics Base, Barstow, CA	Club Street/Eniwetok/Desert View Housing Areas	Congressional	Engine	Heat pump	33	3		99		No	0	Yes	33	No	0	
Marine Corps Recruit Depot, Parris Island, SC	Wake Village Housing Area and Quarters 4 & 8	Congressional	Engine	Heat pump	14	3		42		No	0	Yes	14	No	0	
Marine Corps Air Station, Beaufort, SC	Capehart Housing Area	Congressional	Engine	Heat pump	10	3		30		No	0	Yes	10	No	0	
MCCMC Quantico, VA	District Cooling Plant															Yes

Table 7. Number of DOD installations under natural gas cooling demonstrations.

#in operation = no of installations with systems currently in operation
#under construction = no of installations with systems after construction contract is awarded and before acceptance
#in plan/design = no of installations with systems currently in various stages of design up to ground breaking
#in interest = no of installations with good feasibility but with no committed funding

Services	# in operation		# under construction		# in plan/design		# in interest
Army	4	Engine	4	Engine	1	Engine	8 sites, type-TBD
	0	Absorption	2	Absorption	0	Absorption	
	1	Desiccant	2	Desiccant	2	Desiccant	
Navy	0	Engine	2	Engine	4	Engine	5 sites, type - TBD
	3	Absorption	4	Absorption	1	Absorption	
	1	Desiccant	1	Desiccant	1	Desiccant	
Air Force	0	Engine	3	Engine	0	Engine	2 sites, type-TBD
	0	Absorption	0	Absorption	0	Absorption	
	1	Desiccant	1	Desiccant	0	Desiccant	
Marine Corps	0	Engine	4	Engine	0	Engine	1 site, type - TBD
	1	Absorption	0	Absorption	0	Absorption	
	0	Desiccant	0	Desiccant	0	Desiccant	
Totals	11	installations	23	installations	9	installations	

Installations in operation:
Ft Riley, KS (1 eng unit)
Ft Jackson, SC (1 eng unit operational; 1 eng unit under constr) (*See NOTE 1)
Ft Sam Houston, TX (1 eng unit)
Aberdeen Proving Grnd, MD (1 desic unit)
MacDill AFB, FL (1 desic unit)
National and Naval Hospital, MD (1 absorp unit)
Ft Campbell, KY (3 eng units; 9 eng units under constr; 1 desic unit in plan/design) (**See NOTE 2)
Naval Training Center, IL (1 abs unit operational; 1 abs unit under constr)(***See NOTE 3)
Naval Air Station, Miramar, CA (1 absorp unit)
Navy PWC, Naval Air Station, Pensacola, FL (2 desic units)
Marine Corps Air Station, Yuma, AZ (1 absorp unit)

Installations under construction:
Ft Dix, NJ (1 absorp unit)
Ft Eustis, VA (1 eng unit)
Ft Bliss, TX (1 eng unit)
Ft Polk, LA (1 eng unit)
Ft Hamilton, NY (2 eng units)
Ft Huachuca, AZ (2 absorp units)
Robins AFB, GA (2 eng units)
Davis-Monthan AFB, AZ (2 eng units)
Utah ANG, UT (2 eng units)
Naval Air Station, FL (10 eng units; another bldg in interest)(****See NOTE 4)
Naval Air Station Joint Reserve Base, TX (7 eng units)
Fleet Combat Training Cntr, VA (1 absorp unit)
Naval Air Station, Willow Grove, PA (1 desic unit; 1 absorp unit; 3 eng units operational)(*****See NOTE 5)
Submarine Base New London, CT (1 absorp unit)
Naval Education and Training Cntr, RI (1 absorp unit)
Naval Air Weapons Station, Point Mugu, CA (1 absorp unit)
Marine Corps AGCC, CA (1 eng under constr; 1 eng unit in plan/design)(******See NOTE 6)
Marine Corps Logistics Base, CA (33 eng units)
Marine Corps Recruit Depot, SC (14 eng units)
Marine Corps Air Station, SC (10 eng units)
Ft Myer, VA (1 desic unit)
Ft Benning, GA (1 desic unit)
Keesler AFB, MS (1 desic unit)

Installations in plan/design:
Barnes Bldg (Ft Dix project; 1 eng unit)
Redstone Arsenal, AL (1 desic unit)
Naval Hospital, CA (1 absorp unit)
Naval Air Station, GA (5 eng units)
Naval Air Weapons Station, CA (2 eng units)
Fleet Indus Supply Cntr, VA (1 eng unit; another bldg in interest)(*******See NOTE 7)
Naval Constr Battalion Cntr, CA (1 eng unit)
Navy Air Depot, Jacksonville, FL (1 desic unit; another bldg in interest)(********See NOTE 8)

Installations with interest in program:
White Sands Missile Range, NM - Data Reduction Facility, Bldg 1526
Radford AAP, VA
Ft Gordon, GA
Ft Gillem, GA - New Gymnasium, Bldg 700
Ft McPherson, GA - FORSCOM HQ
Ft Knox, KY
McAlester AAP, OK - Health clinic and Safety office
Scranton AAP, PA - Administration building
Dyess AFB, TX - Four dorms and one office building
Youngstown-Warren Air Reserve Station, OH - Airlift Wing Headquarters
Naval Air Station, Corpus Christi, TX - Admin, Repairs, Maint, Trng, Bldg 8
Fleet Industrial Supply Center, San Diego, CA Administrative, Bldg 1
Fleet Combat Training Center, San Diego, CA - Training Facility, Bldg 24
Naval Air Station, Whiting Field, Milton, FL - Aircraft Simulator, Bldg 2946
Naval Air Oceana, VA - Enlisted Barracks, Bldg 419
MCCMC Quantico, VA - District Cooling Plant

NOTES:
***NOTE 1**: Although Ft Jackson has 1 unit under constr, this installation was already counted; see notation above for Ft Jackson under "Installations in operation".
****NOTE 2**: Although Ft Campbell has 9 eng units under constr and 1 desic unit in plan/design, this installation was already counted; see notation above for Ft Campbell under "Installations in operation".
*****NOTE 3**: Although Naval Training Cntr, IL has 1 absorp unit under constr, this installation was already counted; see notation above for Naval Training Cntr under "Installations in operation".
******NOTE 4**: Although Naval Air Station, FL has an additional bldg in interest, this installation was already counted; see notation above for Naval Air Station, FL under "Installations under construction".
*******NOTE 5**: Although Naval Air Station, Willow Grove, PA has 1 absorp unit under constr and 3 eng units operational, this installation was already counted for absorption units; see notation above for Naval Air Station, Willow Grove, PA under "Installations under construction".
********NOTE 6**: Although Marine Corps Air Ground Combat Cntr has 1 eng unit in plan/design, this installation was already counted; see notation above for Marine Corps Air Ground Combat Cntr under "Installations under construction".
*********NOTE 7**: Although Fleet Industrial Supply Cntr, VA has an additional bldg in interest, this installation was already counted; see notation above for Fleet Industrial Supply Cntr under "Installations in plan/design".
**********NOTE 8**: Although Navy Air Depot, Jacksonville, FL has an additional bldg in interest, this installation was already counted; see notation above for Navy Air Depot, Jacksonville, FL, under "Installations in plan/design".

Table 8. Points of contact for the demonstration sites.

Installation	Facility Type	POC	Telephone	Alternate POC	Alternate Telephone	FAX	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)
Army										
Ft Riley, KS	Irwin Army Community Hospital	Keith Jevons	(913) 239-2044			(913) 239-6678	Engine	Chiller	2	300
Ft Jackson, SC	Central energy plant	Nick Autry	(803) 751-3838	Dwight Williamson	(803) 751-7850	(803) 751-5916	Engine	Chiller	2	700
Ft Sam Houston, TX	Single family detached residential bldg	Karen Walker, Pacific Northwest Laboratory, Washington DC	(202) 646-7794			(202) 646-5233	Engine	Heat pump	1	3
Ft Campbell, KY	Building 3214 (3rd Battalion)	Arlen Wright	(502) 798-0597	Bob Palmer	(502) 798-5668		Engine	Chiller	1	250
	Building 6944						Engine	Chiller	1	360
	Building 6921A						Engine	Chiller	1	570
Aberdeen Proving Ground, MD	Burger King	Gary Testerman	(410) 278-5738				Desiccant	Dehumid unit	1	
Air Force										
Installation	Facility Type	POC	Telephone	Alternate POC	Alternate Telephone	FAX	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)
MacDill AFB, FL	6th Medical Group Hospital	Mr. Jim "Zack" Zaccari, Facility Mngr	(813) 828-5340				Desiccant	Dehumid unit	1	

Table 8. Cont'd.

Navy										
Naval Air Station, Willow Grove, PA	Base Exchange (BX)	Karen Walker, Pacific Northwest Laboratory, Washington DC	(202) 646-7794	Jim Edmond	(215) 443-6939	(202) 646-5233	Engine	Rooftop A/C unit	2	15
	Multipurpose Library	Karen Walker, Pacific Northwest Laboratory, Washington DC	(202) 646-7794	Jim Edmond	(215) 443-6939	(202) 646-5233	Engine	Split system A/C unit	1	15
National and Naval Hospital, Bethesda, MD	Hospital	Krashan Pasirija, Product Engineer	(301) 319-4056		(301) 295-1748		Absorption	Chiller	1	300
Naval Training Center, Great Lakes, IL	Building 237 - Medical and Dental Clinic	Donn Stiner	(847) 688-4731	LT Cody Stice	(708) 688-4464		Absorption	Chiller	2	268
Naval Air Station, Miramar, CA	Building 515 - Electronics/ Hydraulics Maintenance Training	John Gray	(619) 537-6488	Deon Delapena, ROICC officer	(619) 556-2454	(619) 537-1038	Absorption	Chiller	1	180
Navy Public Works Center, Naval Air Station, Pensacola, FL	Environmental Building	John Geurin	(904) 452-3127	Mr. Roger Israel, Repair Shop	(904) 452-3271		Desiccant	Dehumid unit	2	
Marine Corps										
Installation	Facility Type	POC	Telephone	Alternate POC	Alternate Telephone	FAX	Type of NG Cooling	NG Cooling Equip Type	Total No of Units	Tons per Unit (if Eng or Absorp)
Marine Corps Air Station, Yuma, AZ	Building 663: 2 Barracks & Lounge	Ron Durfey	(602) 341-2734			(602) 341-2551	Absorption	Chiller	1	300

3 Discussion of Results

Feedback from the Field

Fort Riley, KS

At the Irwin Army Community Hospital, where two, 300-ton natural gas engine-driven chiller units (designated by chiller numbers 3 and 4, respectively) currently operate, much time has been spent on chiller maintenance. Each chiller has two compressors and two engines. Table 9 gives an abbreviated chiller maintenance history since its initial operation.

MacDill AFB, FL

At the 6th Medical Group Hospital, the 18,000 cfm desiccant unit has been operating since the beginning of June 1996, removing moisture from the 100 percent outside air being supplied to hospital operating suites. Work is in progress to connect the unit to a direct digital control (DDC) system that will monitor the unit's performance, which presently is checked remotely by modem. Air Force contacts all expressed favorable impressions with the contractor's performance.

The entire installation appears to be first-rate, from workmanship to maintenance considerations. There may still be some additional refinements required: water softening for the evaporative cooler water, and some adjustment of the controls to ensure the air supplied is not too dry at any time. The installation is somewhat unusual in that there is a pre-cooling coil upstream of the desiccant wheel, as well as a post-cooling coil. The post-cooling coil is typically required for final sensible cooling and/or some final dehumidification when the outdoor humidity is very high. A pre-cooling coil, usually not provided, was reportedly installed to provide some measure of "insurance" for the user should the desiccant unit not remove moisture as it should.

However, if the desiccant unit is capable of removing some (or all) of the moisture that the pre-cooling coil is now removing, some energy cost savings may be realized by reducing the load on the chiller and increasing the dehumidification load on the desiccant unit. USACERL has recommended that consideration be given to deactivating the pre-cooling coil during a period of time when the operating suites are not in use to see if the sensible and latent loads can be met by the desiccant unit and post-cooling coil only. If so, the pre-cooling coil valve might be closed under more stringent outdoor weather conditions to see if, or under what conditions, use of the pre-cooling coil is really necessary. It may be that the only time the pre-cooling coil is necessary is when either the post-cooling coil or desiccant unit is not functioning properly.

Fort Jackson, SC

The Fort Jackson Central Energy Plant has two, 700-ton natural gas engine-driven chiller units (designated by chiller numbers 1 and 2, respectively); only one of the chiller units is currently operational. Since both chiller units experienced mechanical problems that limit their full load capacity, temporary chillers were installed to compensate for the loss in cooling capacity loads. Table 10 shows an abbreviated chiller system operational log from 1 May through 21 October 1996, which outlines the significant events warranting chiller system shutdown and maintenance.

Table 9. Maintenance history at Fort Riley.

Date	Chiller Unit #	Problem	Corrective Action
9/22/95	4	Analog board failure	Replacement of microprocessor power supply
9/27/95	3	Compressor oil leak	Unit shutdown; both units retrofitted and repaired
10/31/95	3	Evaporator/condenser pump failure	Flow switch repair on 11/28/95
12/20/95	3 and 4	Evaporator/condenser pump failure	Inoperative flow switches
1/18/96	4	Low refrigerant pressure	Shutdown of unit; chiller barrel leak detected
2/1/96	3	High exhaust temp	Exhaust temp sensor and high coolant pressure sensor replacements
3/11/96	4	Chilled water flow switch	Flow switch paddle replacement
3/12/96	4	Analog board failure	Replacement of sensor board
3/19/96	3 and 4	Maintenance	Oil filter replacements; oil samples; vibration analysis
4/8/96	3	Bad timer	New watch dog timer installed
5/2/96	4	Chilled water flow switch	Replacement of switch
7/11/96	3 and 4	High engine coolant temp	Replacement of heat exchangers
7/29/96	3 and 4	Chilled water flow switch	Replacement of flow switches
8/20/96	3	Exhaust heat exchanger ruptured	Heat exchanger replacement
9/9/96	3	Oil leaks	Compressor seal needs replacement
9/17/96	3	Compressor seal	Seal replaced
9/27/96	3	Backfiring	Located bad distributor on one of the engines
10/3/96	3 and 4	Engine	Broken lifter and push rods located; chiller 4 shutdown for valve adjustment
10/9/96	3 and 4	Continuing	Replacement of gas regulators on all 4 engines

Table 10. Operational history at Fort Jackson.

Date	Chiller Unit #	Problem
5/1/96	1	High engine water temp
6/4/96	1	Low water
6/4/96	2	High intake manifold temp
6/6/96	2	Blown fuse plugs on fluid coupling
6/12/96	2	Chiller overload
6/16/96	1	Refrigerant leak
6/30/96	1	High vibrations
7/25/96	1	Service oil change required
8/23/96	1 and 2	Both chillers down for repair
9/14/96	1	Engine over load
10/7/96	2	Low temp suction pressure
10/9/96	2	Low compressor suction pressure
10/21/96	2	Low demand

Navy Public Works Center, Pensacola, FL

Two, 1590-cfm, desiccant units have been installed at the Environmental Building facility. They currently maintain about 45 percent humidity within the facility. Initial problems with controls have been corrected. Preliminary information is that the natural gas usage for desiccant regeneration has been higher (and correspondingly more expensive) than initially anticipated, but the units do provide the environmental conditions that the laboratory requires for operation. The cause of the unexpectedly higher operating cost warrants further investigation, but an alternative electrical vapor compression system with reheat would also be expensive to operate, considering the facility's makeup airflow requirements, the typically high outdoor humidity, and the desired humidity level to be maintained within the space. No daily operational log has been kept due to lack of direct roof access to the desiccant system. There is no staircase or outside ladder provided.

Naval Air Station, Miramar, CA

At the Electronics/Hydraulics Maintenance Training facility at Naval Air Station, Miramar, CA, the 180-ton, natural gas, direct-fired, double-effect absorption chiller unit has been operational since March 1996 and works well. The Naval Facilities Engineering Service Center (NFESC) has been monitoring the performance of the absorption chiller since June 1996. Suggestions to improve the quality of design and commissioning of natural gas cooling equipment were:

- Natural gas piping lines 3 in. in diameter should not be on the roof.
- The fire code must be the determinant in construction and cost.

- Specifications should be written according to what power is available (e.g., parasitic loads).
- Comments must be given to those doing design review early in the process.
- Anticipate commissioning problems and allow memorandums of agreement (MOAs) to be written.
- Strong commitment from Public Relations Department is helpful.

Marine Corps Air Station, Yuma, AZ

At the Marine Corps Air Station, a 300-ton, natural gas, direct-fired, double-effect absorption chiller unit in the Barracks and Lounge facility has been operational since March 1996, but did not get commissioned until April 1996. No major problems have been encountered with the absorption chiller throughout the summer season. The Naval Facilities Engineering Service Center (NFESC) has been monitoring the performance of the chiller since June 1996. A new addition is currently under construction at the Marine Corps Air Station to a medical clinic, where a new natural gas chiller has been proposed.

Naval Training Center, Great Lakes, IL

The two, 268-ton, direct-fired, double-effect, natural gas absorption chiller units at the Medical and Dental Clinic (Building 237) have been operational since March 1996. The Naval Facilities Engineering Service Center (NFESC) has been monitoring the performance of the chiller units since June 1996.

Fort Campbell, KY

Currently three natural gas engine-driven chillers have been installed and are operational:

- one 250-ton unit at Building 3214 (3rd Battalion)
- one 360-ton unit at Building 6944
- one 570-ton unit at Building 6921A.

The major problems encountered during chiller operations were:

- water treatment problems (e.g., lime deposits in the tubes of one of the heat exchangers)

- check valve problems (isolation valves suggested to service compressors, O-ring seals, etc.)
- alignment troubles resulting from couplings.

Aberdeen Proving Ground, MD

The Burger King restaurant at Aberdeen Proving Ground has a 2000-cfm desiccant unit currently operational. The unit has performed well in producing a comfortable environment. However, maintenance is critical; the project needs to be turned over to a service contractor for maintenance.

National and Naval Hospital, Bethesda, MD

The National and Naval Hospital in Bethesda, MD currently has an operational 1000-ton, direct-fired, double-effect absorption chiller.

Pacific Northwest National Laboratory Activities

The Pacific Northwest National Laboratory in Richland, WA has been involved in the New Technology Demonstration Program (NTDP) sponsored by the U.S. Department of Energy (DOE), in conjunction with support from DOE's Federal Energy Management Program (FEMP) and the DOD Strategic Environmental Research and Development Program (SERDP). The following DOD sites have natural gas cooling projects as part of the NTDP.

Fort Sam Houston, TX

Reports have been completed on the results of field monitoring and evaluation studies for a residential natural gas engine-driven heat pump at Fort Sam Houston in San Antonio, TX based on the 1994 cooling and 1994-1995 heating seasons. No forced outages occurred during the 1994 cooling season, resulting in a 100 percent reliability record for the gas engine-driven heat pump (Miller 1996). During the 1994 cooling season, the thermal coefficient of performance (COP) for the heat pump was 1.128. During the 1994-1995 heating season, the overall system gas test-period coefficient of performance (TP_COP) was 1.28 including the auxiliary heater (Miller 1995a; 1995b), compared to a TP_COP of 1.35 without auxiliary heat (Miller 1996).

Willow Grove Naval Air Station, PA

In May 1992, two, 15-ton, natural gas engine-driven air-conditioning units were installed at the Willow Grove Naval Air Station Base Exchange (a 15,000 sq ft retail store). Performance monitoring occurred from June 1992 to July 1993. Results showed that the natural gas air-conditioning system had a net life-cycle energy cost savings of $121,381 (1995 dollars), which is based on the present value of life-cycle cost savings of $148,023 (compared to electric powered units at the same site) minus the increased total investment of $26,642 (Armstrong and Katipamula 1996).

In September 1993, a 15-ton, natural gas, split-system (reciprocating compressor/air-cooled condenser) unit was installed at a multipurpose library and office space at the Willow Grove Naval Air Station, with performance monitored from May to October 1994. Reports for both the Base Exchange and library projects are now completed.

Lessons From the Demonstration

In a recent survey of private sector energy engineers by the Association of Energy Engineers (AEE), the overall performance of the gas cooling equipment received a wide range of ratings between very good (10.4 percent) and very poor (3.7 percent) (Association of Energy Engineers 1996). Although the majority of the users (60 percent) reported a favorable experience with the performance of the gas cooling equipment, a significant portion of users (40 percent) reported negative experience. A similar trend among the DOD users is noted in the feedback from the field as shown in the previous section.

The majority of the DOD demonstration systems showed satisfactory cooling performance. The cooling COP of 1.28 for a small engine-driven heat pump at Fort Sam Houston exceeds the typical industry expectation of 0.9 (Table 1). Since most of the demo systems in operation are still in the first year monitoring stage, it is too early to gather an accurate assessment of cooling performance of these systems. Continuous monitoring of performance of these systems should provide accurate analysis of energy efficiencies and economical benefits of these systems.

A number of DOD installations also reported problems in the operation of the gas cooling systems. Note that the majority of the problems experienced in the field occurred during the early days of operation. The reported problems are mostly associated with the minor malfunctions either due to poor quality components (as shown in the Fort Riley and Fort Campbell systems) or inexperienced design (as suggested by the system at the Naval Air Station, Miramar, CA).

Environmental Benefits

> Since natural gas is a clean burning fuel, when it is applied as a power source to fire gas cooling systems, it provides an advantage over electric-powered systems. By installing a natural gas cooling system, the need for peak electric air-conditioning is avoided and lessens the need for more electric power from generating plants (American Gas Association 1994).

The environmental benefit from the 42 gas cooling demonstration systems was analyzed with the Renewables and Energy Efficiency Planning (REEP) program (Nemeth et al. 1995). The REEP analysis shows the total reduction of pollutants as following: SOx abated by 232 tons/yr, NOx abated by 55 tons/yr, particulate matter abated by 4 tons/yr, CO_2 abated by 8290 tons/yr, and CFCs displaced by 39,008 lb/yr.

Further Recommendation

The early results from the demonstration program shows a strong potential of the gas cooling systems to provide cost effective and reliable cooling to the DOD facilities. Due to the early stage of the gas cooling technology, however, a number of systems experienced problems especially in the engine-driven systems. The problems will be resolved as the designers and the operators gain further experience with gas cooling systems.

The standard design guide and commissioning procedures would be useful tools for the DOD engineers to eliminate the problems experienced in the demonstration program. A detailed case study from a few selected systems is urgently required to provide valuable inputs for these tools. The study should include analysis of successful systems to identify factors leading to a successful system. Analysis of design deficiencies and pitfalls will prevent similar problems as experienced during the demonstration.

4 Summary and Recommendations

Natural gas cooling systems are currently in operation at 11 DOD installations, under construction at 23 installations, and in design at 8 installations. Preliminary reports from the DOD users in the field show that natural gas cooling systems have a strong potential for use in DOD facilities. A number of installations have reported problems in the early stage of system operation, which reflects a similar trend reported in the private sector. Development of standard design guide and commissioning procedures will help DOD engineers eliminate such problems.

A detailed case study of a few selected systems is strongly recommended to generate inputs to these tools. Continuous monitoring of ongoing demonstrations is also strongly recommended to ensure successful implementation of gas cooling technology at DOD installations.

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ATTN: Engrg & Srvc Lab

USA TSARCOM 63120
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American Public Works Assoc. 64104-1806

US Army CHPPM
ATTN: MCHB-DE 21010

US Gov't Printing Office 20401
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Nat'l Institute of Standards & Tech
ATTN: Library 20899

Defense General Supply Center
ATTN: DGSC-WI 23297-5000

Defense Construction Supply Center
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Defense Tech Info Center 22060-6218
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SERDP Support Office 22102

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